[SD1][SD2]

The Effects of Grazing on Soil Physical and Chemical Properties and Plant Diversity in North-Central Alberta

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Abstract

The grazing of livestock is often harmful, causing degradation of the land[SD3] but it can also act as a natural disturbance that contributes to the health of an ecosystem. This suggests that the effects of grazing involve interactions between the grazing regime and the properties of the particular study area, showing that a generic approach to grazing management will prove ineffective. This study compared soil chemical and physical properties and plant diversity between a grazed (GR) and grazing excluded (GE) plot in a north-central Alberta location in order to determine the effects of grazing in this region where, to my knowledge, no similar study has been conducted. Results showed that grazed land was associated with increased bulk density and decreased soil moisture and plant diversity. The grazed study area also had higher levels of bare ground and a greater proportion of invasive species. The sand fraction of the soil in the grazed area was 11% higher than in the non-grazed area, providing evidence for erosion. Soil moisture was the measurement most significantly affected by grazing ($p = 6.09E-10$), suggesting that management strategies in north-central Alberta should focus on this parameter.

Keywords: Grazing, North-central Alberta, soil properties, vegetation properties.

Introduction

Alberta is a province well known for its contribution to the cattle industry, producing the greatest number of cattle in all of Canada (Statistics Canada[SD4]).The southern parts of the province yield the majority of the cattle produced. However, the livestock industry in north-central Alberta is also strong, reaching a market value of 260 million dollars in 2011 ("Agriculture, Alberta Canada").

The overgrazing of land is an ancient problem that has existed for as long as livestock have been domesticated. Substantial environmental problems are associated with land that has been degraded because of grazing livestock. Decreases in plant cover allow for soil erosion (Pei and others 2008), and the rapid evaporation of moisture (Teague and others 2011). Certain palatable woody and herbaceous species are selectively targeted by livestock (Jones and others 2011), reducing overall diversity. Soil can become compacted as a result of trampling, resulting in higher "bulk density[SD5]" which reduces soil pore space and restricts water and oxygen movement (Zhao Y [SD6]and others 2011). The net removal of plant life often results in nutrient deficiencies (Sousaand others 2011) which the patchy return of nutrients through urine and manure is often insufficient to replace (Whitehead and Raisrick, 1993).

Another side to the effects of grazing does exist. Some studies have found grazing to function as a natural disturbance that can act as a selective pressure to maintain the health of an ecosystem (see for example, Papnikolaou and others 2011 and Smoliak and others 1972). Many more studies yield results showing a mixture of both positive and negative effects of grazing(See for example, Pinero and Others 2009, Gan and others 2012).These inconsistent findings clearly display what has always been well known about the effects of grazing: that these effects differ from region to region (Lavado and others 1996). North-central Alberta is an area that is currently lacking in quantitative research on the effects of grazing, despite the cattle industry's prevalent presence in the region. The purpose of this study was to compare soil chemical and physical properties (bulk density, soil moisture content, PH, organic matter content and nitrogen, phosphorous, and potassium levels), and plant diversity between a grazed and grazing-excluded plot in north-central Alberta in order to determine what effect, if any, cattle grazing has on the land in a more northern Alberta context. The results of this study provide quantitative evidence on the impacts of grazing in north-central Alberta, creating the potential for improvements in land use.

Methods[SD7]

Study Area Description

The study area is located on a farm in Fawcett, Alberta, approximately 135 km north of Edmonton, placing it in north-central Alberta. The average annual precipitation for this region is 52 cm, with average summer temperatures of 16.1°C and 124 frost free days (“Alberta Community Profiles: Westlock”). Fawcett falls within the Boreal forest ecoregion of Alberta. The dominant soil type in this area is Gray Luvisol but Dystric and Eutric soils are also found (usually associated with sandier soil) and the dominant plant community type is mixed forests of Aspen, White Spruce and Balsam Poplar (“Natural Regions and Subregions of Alberta[SD8]”). This area has experienced historical grazing pressure from Bison (*Bison bison*) since the Pleistoceneice age (“Bison of British Columbia[SD9]”).

http://en.wikipedia.org/wiki/Fawcett,_Alberta

Figure 1. Location of the study site: Fawcett, Alberta[SD10]

The study area consisted of two adjacent fields: one that had been grazing excluded (GE) in 2005 (for seven years at the time of the study) with an area of about five acres and one that continues to be grazed during the growing season (GR), with an area of about a hundred acres.

Study Area History

Both sites are similar in terms of their human use history. Until its exclusion in 2005, GE had been used for grazing purposes since 1992. GR has been utilized for grazing purposes since 1987. The stocking rate has consistently been around 1.03cows/ha, a moderate grazing pressure. Both fields were cropped with barley before being used for grazing purposes. When the transition was made from cropped to grazed land, both fields were seeded with a mixture of brome, timothy and orchardgrass.

Sampling method

In May 2012, the two adjacent studyplots (GE and GR), were first divided into plots of equal size (about 5 acres each). The physical closeness of the two study areas and their similar human use history leads to the expectation that, prior to the enclosure being established in 2005, GE and GR were similar in terms of vegetation and soil characteristics. These two plots were then divided into separate 10m by 10m plots. Using a random numbers table, ten different 10m by 10m sampling plots were selected for both GE and GR. Four random soil samples were taken from each plot using a stainless steel soil corer to a depth of 25 cm. These samples were combined to get a composite sample for each sample plot (a total of 20 different soil samples, 10 from GE and 10 from GR). These samples were frozen until they could be analyzed at Concordia University College of Alberta starting in October, 2012.

Figure 2. The two study plots, with GE on the right and GR on the left[SD11].

Plant Diversity Analyses

In August 2012, a microplot (25x60 cm) was randomly tossed five times within each 10m by 10m sampling plot. Each species in the microplot was identified and percent cover estimated (Daunbenmire A[SD12]nalysis). Percent cover was estimated by looking down on the plot from above.Any woody species present were identified, and height and diameters were measured. Using this information, the Shannon Index (See Appendix, pg.27 for formula) was calculated to determine diversity differences and grazing inventory forms were used to determine range health. Average circular area/m2, average number of individuals/m2, relative density, frequency and coverage and relative importance values were also calculated using the woody species data that was collected.

Percent Bare Ground, Invasive Species and Litter Coverage

Percentage of bare ground, invasive species and litter coverage was obtained for each 10m by 10m plot using an average of the five Daubenmire tosses. These ten values (from the ten 10m by 10m plots) were then added together and averaged to get a total representative value for GE and GR.

Soil Analysis

Bulk density of the soil was determined by dividing the weight of oven-dried soil by its volume (Dalton, 2010) (See Appendix, pg. 28 for formula).

Soil moisture content was determined by weighing #100 (150 mm)sieved soil before and after being oven-dried at 110°C for 24 hours (Dalton, 2010) (See Appendix, pg.28 for formula).

Figure 3. Oven-dried soil

Soil organic matter content was calculated by measuring the ash-free dry weight of the samples. Oven-dried samples were subjected to a muffler furnace set at 500°C for about 12 hours (Dalton, 2010) (See Appendix, pg.28 for formula).

Figure 4. Soil samples cooling off[SD13] after coming out [SD14]of the muffle furnace

Soil composition was determined by taking equal weights of the ten soil replicates from each study site and combing them to form two samples: one made up of samples from all the replicates in the GR site and one made up of samples from all the replicates in the GE site. These combined samples represented the average soil composition of each field. The sand fraction of the soil was separated from the silt and clay fraction using a 1/2 mm, a 1/4 mm and a 1/8 mm sieve to give separated fractions of coarse sand, medium sand and fine sand particles (respectively), from the smaller silt and clay particles.

Soil nitrogen, phosphorous, potassium and PH were determined at the field site (August 2012) with the use of a LaMotte soil sampling kit.

Data Analysis

The average of three replicates of bulk density, soil moisture, and soil organic matter measurements was taken for every sampling plot and a one-way ANOVA applied on the results.

Differences in PH, and percentage coverage of invasive plants, bare ground and litter were also tested for significance with a one-way ANOVA. Because this study involves the comparison of two adjacent pastures, pseudoreplicates are being dealt with. To address this, the method described by Bauer and others (1987) was employed. This method involves treating each sampling site as a replicate so that statistics can be used on the data collected. This would mean that each sampling plot would have ten replicates because ten separate sampling plots were established. As long as this awareness of pesudoreplicates is kept in mind, the statistical analysis of the data will provide valuable information. [SD15]

Results

Temperature and Precipitation

During the study period, total precipitation was recorded as 5.9 inches[SD16] for the two months leading up to the site sampling (July and August) and the average temperature was 24°C.

Summary of Results

The grazed plot (GR) was found to possess a greater proportion of bare ground and a lower percent coverage of litter. Soil moisture was significantly greater in the grazing- excluded plot (GE), and bulk density was significantly lower. Organic matter content of the soil in GE was greater than in GR, but not significantly so. The soil in GR possessed a greater proportion of sand. Plant diversity was lower in GR than in GE.

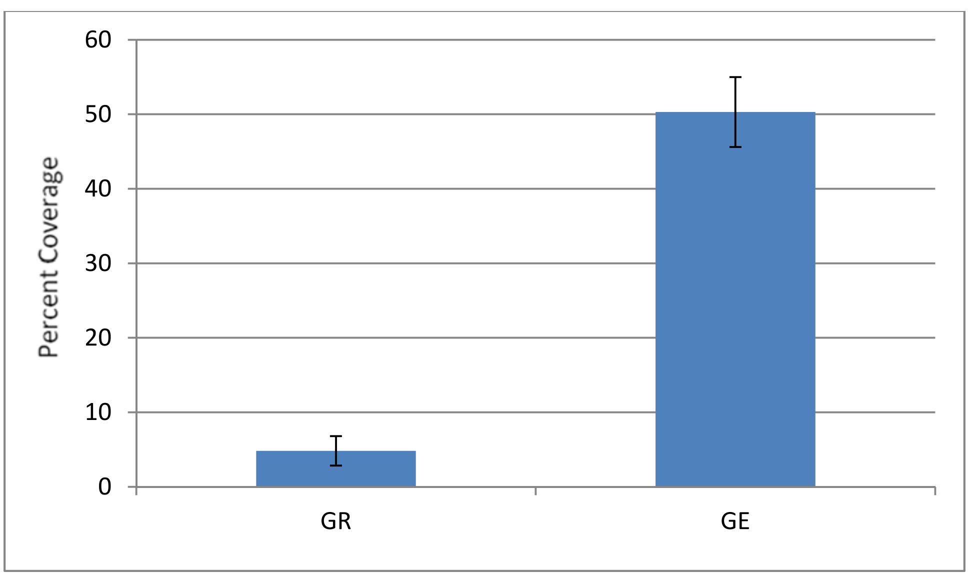


Figure 5. Differences in average percent coverage litter between GE (non-grazed plot) and GR (grazed plot). Error bars calculated from standard error.

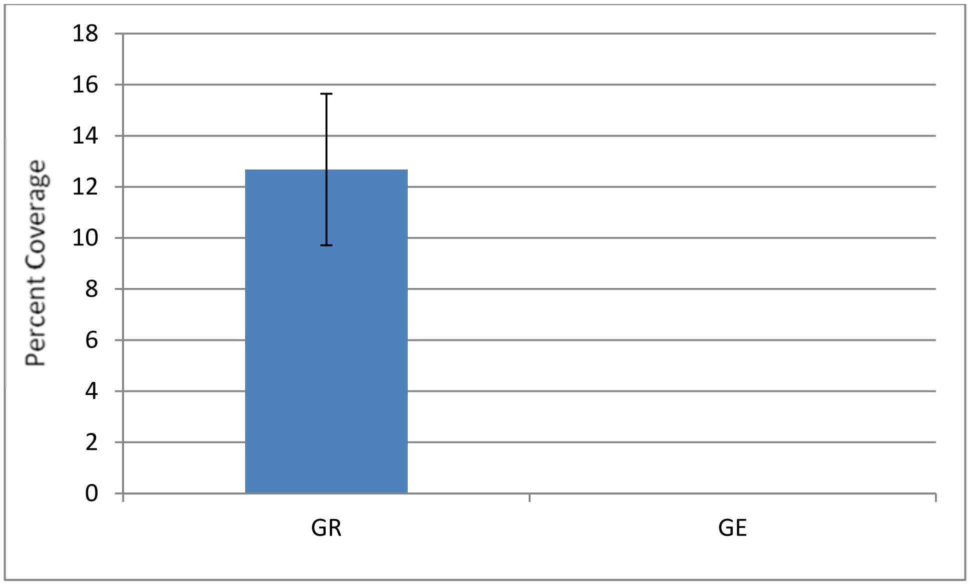


Figure 6. Differences in average percent coverage of bare ground between GE and GR

Marked differences in soil and vegetation between GE and GR were evident during data collection. The soil in the grazed plot (GR) was paler and sandier than the soil in the grazing excluded plot (GE) (see Table 1 for soil composition data). As would be expected, grass species were taller in GE and much of the ground was covered in litter. On average, 50.3% of the ground coverage in GE was due to litter coverage (see Figure 5). This contrasts with GR, where litter was less present (GR had only 4.82% of its ground coverage accounted for by litter) and bare ground was observed (see Figure 6). No bare ground was present in GE because where ground coverage was not accounted for by living plant cover, it was covered by dead plant material (the plant litter). Differences in litter coverage and bare ground between GE and GR were significant when tested with one-way ANOVA ($p = 4.94E-08$ and $p = 0.00074$, respectively).

Soil Characteristics

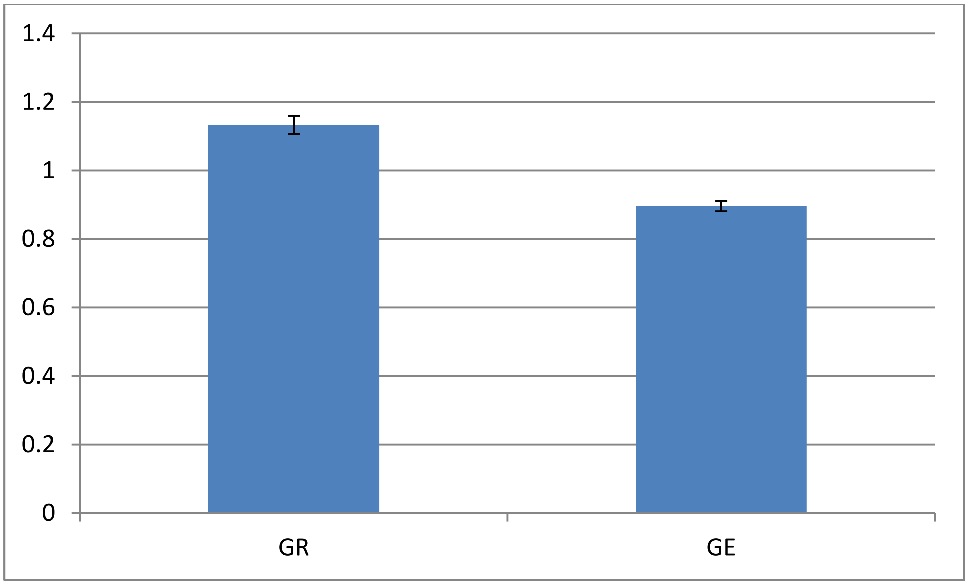


Figure 7.Differences in bulk density (in g/mL) between GE and GR.

Bulk density was significantly greater (p = 2.19E-06) in GR compared to GE (see Figure 7).

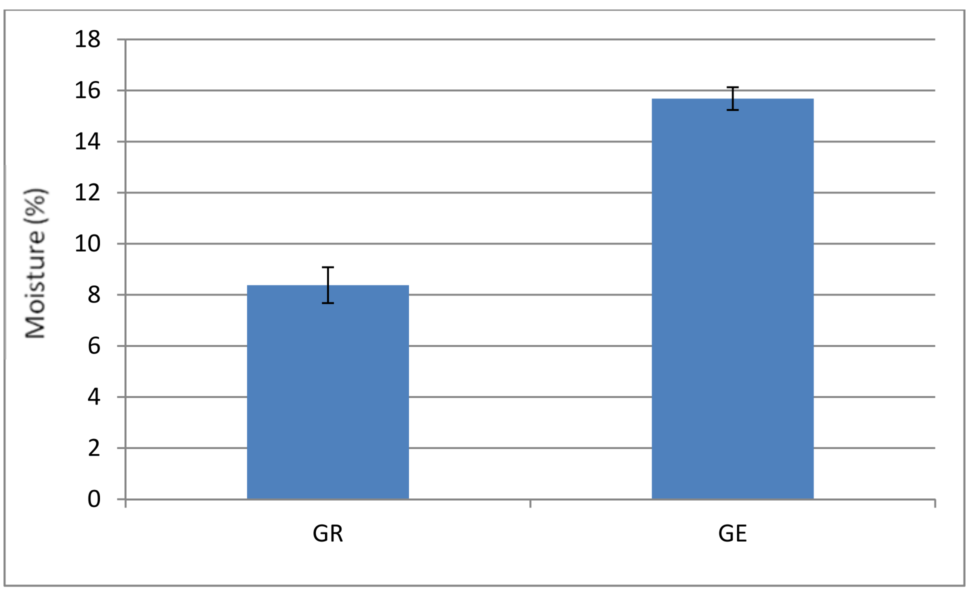


Figure 8. Differences in soil moisture (as % of Soil Weight) between GE and GR

Soil moisture content was significantly less (P = 6.09E-10) in GR compared to GE (see Figure 8), with a difference of 7.3% between the two in terms of soil moisture.

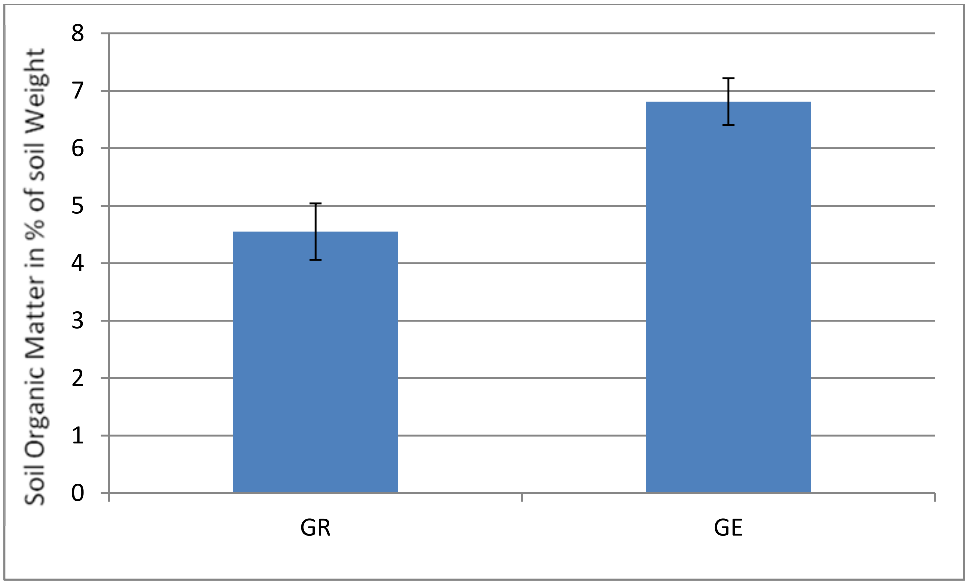


Figure 9. Differences in soil organic matter (as % of soil weight) between GE and GR

Organic matter content of the soil was greater in GE than GR, but not significantly so (p= 0.0712) (See Figure 9).

Table 1. Soil Composition Differences Between GE and GR[SD17]

	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt and Clay (%)
Grazed	0%	19.40%	68.90%	11.70%
Non-grazed	0%	5.80%	70.90%	23.30%

Table 1 shows that soil composition differences between GE and GR were striking, with GR possessing a larger amount of sand (by 11%) and a lower amount of silt and clay.

Table 2. Soil nutrient levels of GE and GR

	Potassium	Phosphorous	Nitrogen
Grazed	High	Low	Low
Non-grazed	High	Low	Low

Table 2 shows that levels of soil nutrients (potassium, phosphorous, and nitrogen) did not differ between the two treatments.

PH was found to be higher (less acidic) in GR when compared to GE (7.5 as compared to 6.8) (data not displayed in a table).

Plant Community

Table 3. Average percent coverage and diversity of herbaceous species in GE (Grazing Excluded plot) and GR (Grazed Plot[SD18])

Herbaceous Species	**GE**	**GR**
Bromus inermis Leyss.	15.2	24.22
Bromus beibersteinii	7.27	13.86
Dactylis glomerata L.	8.02	15.62
Poa fendleraina (Steud.) vasey	5	3.38
Poa pratensis	0.58	6.02
Elytrigia repens	0.1	0.26
Trifolium repens	0.98	8.1
Equisetum pratense	1.78	0.3
Medicago lupulina	0.2	1.02
Cirsium arvense	0.6	0.9
Taraxacum offcinale	0.52	0.92
Astrgalus adsurgens		0.22
Spiraea alba	0.004	0.1
Poa secunda	3.32	
Deschampsia cespitosa	3.26	
Fragaria vesca	0.16	
Shannon Diversity Index	**2**	**1.51**

Table 4. Number of individuals and diversity of woody species in GE (Grazing Excluded plot) and GR (Grazed Plot)

Woody Species	**GE**	**GR**
Populus nigra	2	29
Ceanothus cuneatus	5	7
Populus alba	27	0
Populus balsamifera	2	0
Shannon Diversity Index	**0.65**	**0.49**

Shannon Diversity Index calculations for the herbaceous diversity of GE and GR yielded a greater diversity index for GE (2 as compared to 1.81) (see Appendix, pg.33 for calculations). Table 3 lists the different species found in both GE and GR, along with average percent coverage of each species. A wider variety of different species was found in GE (15 different species in GE as compared to 13 in GR). Two species of grass, *Poasecunda* (Sandberg Bluegrass), and *Deschampsiacespitosa* (Tufted Hairgrass) were found in GE but not in GR.

Woody species diversity was greater in GE than GR (Shannon Index of 0.65 as compared to 0.49). Four different woody species were present in GE, while only two were present in GR (Table 4). Relative importance values reveal that, on average, GR yielded greater importance values for any one woody species with an average value of 1.5 as compared to 0.75 (Data shown in Appendix, pg. 35).

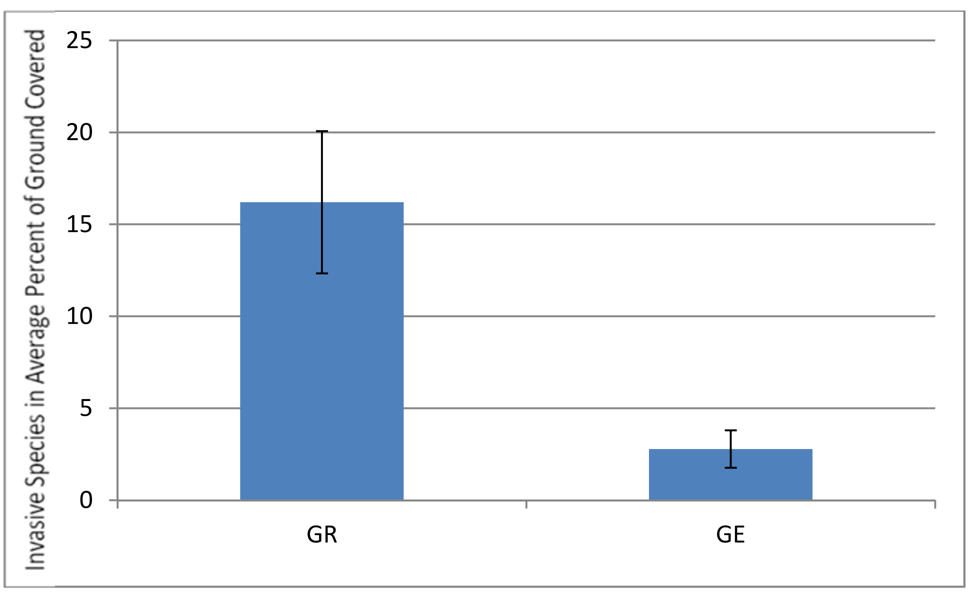


Figure 10. Difference in invasive species coverage (in average % ground covered) between GE and GR

There was a larger percent coverage of invasive species in GR as compared to GE ($p = 0.00352$) (see Figure 10).

Discussion

Overall, livestock grazing was a disturbance that negatively impacted the health of the study site. This study found that grazing was associated with greater bulk density, coarser soil, lower soil moisture, reduced herbaceous and woody species diversity and a larger percent coverage of bare ground and invasive species. This suggests that Northern Alberta's history of being grazed by bison was not sufficient to protect against the effects of cattle grazing, perhaps because cattle and bison target different species (Stueter and Hidinger, 1999).

Bulk Density and Moisture

Bulk density, a measure of how tightly packed the soil is, can have serious implications for the functioning of the soil ecosystem. Bulk density was found to be greater in GR than in GE, suggesting that the treading action of the cattle resulted in a denser, more compact soil (Herbin and others 2011). Pore spaces are smaller in tightly packed soil, reducing the amount of water and oxygen that would normally collect in these pores and making it more susceptible to erosion (Abdelkadir and Yimer 2011). The differences in bulk density between the grazing treatments may be influencing the soil moisture trends that were found in this study. Soil moisture accounted for a larger percentage of GE's soil weight when compared to GR's soil weight. The greater bulk density in GR was a likely contributor to this because compacted soil encourages water run-off, not infiltration (Houlbrooke and others 2011). Studies by Zhao and others, 2011 [SD19]and Herbin and others, 2011 have also found greater bulk density measurements to be correlated with lower soil moisture. Other contributing factors to GR's relatively low soil moisture include its coarse soil and its high levels of bare ground, along with a lack of an insulating litter layer. The sandier soil of GR would allow moisture to drain more easily than the finer textured soil of GE ("Soil and Water Relationships"). There was virtually no exposed ground to be found in GE because, in the absence of grazers, a carpet of plant litter was able to accumulate. This litter shades the ground and limits evaporation rates (Teague and others 2011), contributing to the greater soil moisture in GE. Soil temperature recordings support this association between high amounts of litter and reduced moisture evaporation: the soil temperatures recorded in GE were lower than those recorded in GR (12.2°C as compared to 13.9°C).

Soil Nutrients and Organic Matter Content

The higher amount of plant material being returned to the land in GE leads to the expectation of higher levels of nutrients and organic matter in the soil. However, differences in organic matter between the two study sites were not significant and nutrient levels also showed no differences. This may be due to the lower soil temperatures in GE restricting decomposition and the return of nutrients to the soil. As well, soil nutrients may be returning to the soil in GR through livestock excreta. A study by Prieto and others, 2011[SD20] found that nitrogen inputs through livestock manure and urine was able to counteract the negative effects of grazing. Likewise, a study by Flores and Tracy 2012[SD21] found that phosphorous levels in the soil increased with increasing manure depositions. So despite the fact that nutrient return through livestock excreta is patchy, it could be counteracting the soil nutrient loss that would be expected in GR. Additionally, GR had less aboveground biomass, which can lead to a decrease in the amount of nutrients being taken out of the soil by plants (Henderson and others 2004). It is possible that differences between GE and GR will increase with increasing time of grazing exclusion. A study[SD22] by Miller and others ~~2010~~[SD23], conducted near Lethbridge, also found no significant differences in carbon, nitrogen and phosphorous levels between their grazed and grazing[SD24] –excluded plots, partly attributing it to a short period of grazing exclusion (six years).

Soil P[SD25]H

The higher P[SD26]H found in GR may be a by-product of erosion. As the depth of a soil profile decreases, carbonates come closer to the surface, which can lead to an increase in PH (Dormaar and Willms, 1998). As well, grazing excluded plots are often associated with higher root biomass and a more active rhizosphere (Hinsinger and others 2003).During the decomposition process, roots secrete organic acids (-COOH) and both the roots themselves and the microorganisms living around them release CO2[SD27]. Both CO2 and –COOH are capable of decreasing P[SD28]H levels.

Soil Composition

The coarser soil found in GR (11% more sand than what was found in GE), indicates erosion. The lighter particles of silt and clay are easily washed or blown away through erosion, leaving the heavier particles of sand behind (Pei and others 2008). The high levels of bare, exposed ground in GR supports the possibility that erosion was occurring in GR and causing the differences in soil composition between the two treatments.

Woody and Herbaceous Community

The lower diversity of woody and herbaceous species found in GR may be due to its low soil moisture (Duetsch and others 2010) and selective grazing (Jones and others 2011). Cattle are very destructive towards woody species and they are often a target, both for nutritional value and as scratching posts. The Black Popular saplings found in GR were often broken, with only a few branches yielding live leaves. As only two individuals of Black Poplar (*Populus nigra*) were found in GE compared to the 29 individuals found in GR, a comparison of the heights of these saplings between the two grazing treatments is not feasible. Buckbrush (*C. C*[SD29]*uneatus*) was the one other woody species found in both GE and GR. It was more numerous[SD30] in GR and reached greater heights (0.79m as compared to 0.51 m, see Appendix, pg.34 for calculations). Buckbrush is a common perennial weed and[SD31] has been known to reduce forage yield in pastures because of its superior root system (Defelice MS, 1991). The greater prevalence of this species in GR further suggests its degradation and hints at the reduced viability of GR both now and in the future.

On average, the relative importance values of any one woody species were greater in GR than GE (see Appendix, pg.31 for formula and pg.35 for calculations). This not only suggests that grazing can create a monotypic sapling community but also that the loss of any one of the species found in GR could have a profound impact on the community. In contrast, GE's wider diversity of woody species and their lower relative importance values suggests a healthier ecosystem that may be more resistant to changes, such as the loss of a species.

Selective grazing would also have played a part in reducing the herbaceous diversity. The two species of grass found in GE but not in GR, Tufted Hair Grass (*D. cespitosa*) and Sandberg Bluegrass (*P. S*[SD32]*ecunda*), are palatable to livestock ("Tufted Hairgrass", "*Poasecunda*") and so it can be suggested that their absence was due to the grazing pressure. As well, the greater percent coverage of invasive species in GR (about 15%) suggests that the site is on its way towards becoming a community dominated by non-palatable species that are able to deal with the higher levels of bare ground and lower moisture. Invasive species have the ability to take over a community, reducing diversity so the relative higher levels of invasive species in GR could be contributing to its lower plant diversity.

Summary of Results

Grazing was found to have a substantial influence on the land in northern Alberta, negatively influencing: 1) Soil- Reduced [SD33]levels of organic matter and soil moisture and increased levels of bulk density were associated with the grazed treatment and 2) Vegetation- Both [SD34]herbaceous and woody species diversity was lower in the grazed treatment and it possessed a greater proportion of invasive species.

Implications for Grazing Management

Evidence for erosion in GR was high: a coarser soil texture (erosion washes or blows away finer soil particles, leaving the heavier, coarser particles behind), bare ground, (leaves the soil exposed to erosion), a relative lack of organic matter (organic matter is found in the topsoiland is easily lost through erosion), a relatively high PH (as mentioned above, the study by Dormaar and Willms 1998 i[SD35]ndicates that soil loss through erosion can manifest itself as high levels of PH) and the high bulk density (Su and others 2004) have all been found to contribute to and/or be indicators of erosion. This is something that farmers in the area should be aware of, not only because of the damage it does to their own land but also because of its potential to pollute nearby water bodies (Cournane and others 2011). This particular study site was located along the Pembina River and numerous[SD36] other farms in the area also have grazed land bordering rivers because it is a convenient way to water cattle. Therefore, this study demonstrates the need for erosion reducing practices, such as planting shelterbelts. The Prairie Shelterbelt Program (PSP), managed by Agriculture and Agri-Food Canada operates in Alberta, Saskatchewan and Manitoba, providing subsidized trees for farmers for the purpose of erosion reduction on grazed or cropped lands. This study supports the need for such a program. Farmers may also want to consider increasing litter coverage on their grazed land by, for example, overwintering cattle on their summer pasture. A study by Junginstich and others 2011, as discussed below, demonstrated the benefits of such a practice.

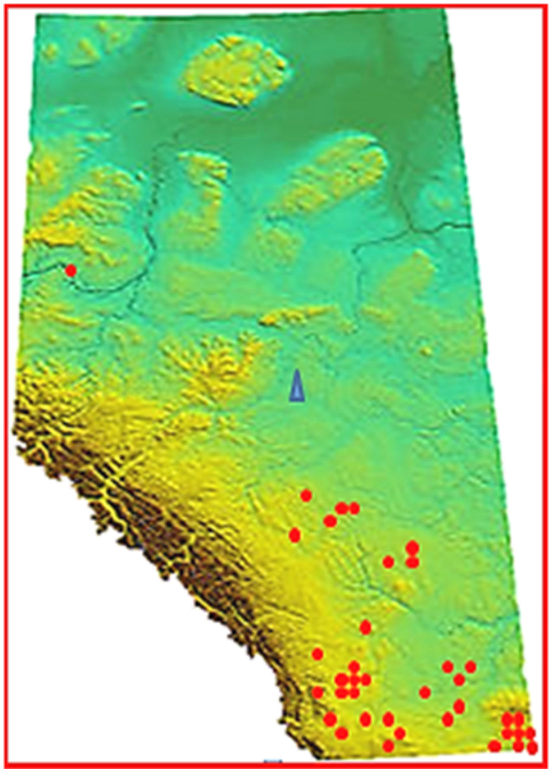
Soil moisture was the most severely affected by grazing, suggesting that management strategies should target this parameter. Straw mulch has been found to reduce run-off (Gholami and others 2013) and the study by Jungnitsch and others in 2011 found that over-wintering cattle on the pasture that will be used in the summer can increase forage growth which would, in turn, increase litter coverage and organic matter content, both of which serve to increase soil moisture levels in the summer (Duetsch and others 2010) and also to reduce erosion, which although not measured directly in this study, was probably contributing greatly to the degradation seen in GR.

Agreement with Other Albertan Studies

The findings of this study were not unexpected and agree well with studies conducted in the more southern parts of the province: Dormaar and Willms, 1998 (Lethbridge) and Chanasyk and Naeth, 1995 (Stavley) also found increased bulk density under their grazed treatment. Henderson and others 2004 (west of Medicine Hat) found increased litter coverage in their grazing excluded treatment and Duetsch and others 2010 (Kinsella) found that increased litter reduced soil temperatures and increased soil moisture. Miller and others 2010 (Lower Little Bow watershed) also found no differences in nitrogen, phosphorous and soil carbon between their grazed and non-grazed treatments.

Future Directions

Figure 11, found on the following page, provides an idea of the current distribution of grazing studies in Alberta. This map does not show all of the grazing studies conducted in Alberta, just a random sample of 27different studies (see Appendix, pg.36 for a list of all the studies used in this diagram. Multiple locations were used in some studies so there are more than 27 points on the map). Clearly, research has been skewed towards the more southern parts of the province. This distribution is intuitive since the cattle industry *is* most prevalent in Southern Alberta. However, the owners of the 3,539 farms in North-Central Alberta alone ("Agriculture, Alberta Canada") might have something to say about this distribution. The current study represents a step towards the goal of making the northern parts of the province just as well-studied as the southern parts. However, larger scale and longer term grazing studies that avoid the problem of pseudoreplicates are needed.



Legend:

Location of present study

Location of previous grazing studies in Alberta

Figure 11. Distribution of grazing studies in Alberta.[SD37]

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Appendix

A. **Formulas:**

Plant Community Analysis Formulas:

- **Shannon Index:**

$$H' = -\sum^{s} p_i \log p_i$$

-Where H' = the Shannon Index, p_i = proportion of total number of individuals composed of species i, log = natural logrithim, and s = number of species in the community

(Freedman et al, 2011)

- **Average Circular Area:**
  A = circular area/ total area sampled

- **Average number of individuals per meter squared:**
  n = # of individuals/ total area sampled
- **Relative Density:**
  $RD_i = n_i / \sum n$

-Where RD_i = relative density, n_i = # of individuals for that species, $\sum n$= total # of species found

- **Relative Frequency:**
  $Rf_i = f_i / \sum f$

-Where Rf_i = relative frequency, f_i = species frequency, $\sum f$ = total species frequency

- **Relative Coverage:**
  $RC_i = C_i / \sum C$
- Where RC_i = relative coverage, C_i = estimated coverage, $\sum C$ = total species coverage
- **Relative Importance Value:**
  $IV_i = (RD_i + Rf_i + RC_i)/3$
- Where IV_i = relative importance value, RD_i = relative density, RF_i = relative frequency, RC_i = relative coverage

Soil Analysis Formulas:

- **Bulk Density:**

  Bulk Density = mass (g)/volume (cm cubed).

- **Soil Moisture:**

  Soil moisture = (weight of soil water/weight of the oven dried soil) x 100).

- **Organic Matter Content:**

  Organic Matter content = oven-dried weight of soil – muffler dried weight/ weight of oven-dried soil).

C. Shannon Diversity (Herbaceous Species)

Grazed

Species	Ni	Pi	lnPi	-(Pi x lnPi)
Ascending Purple Milk Vetch	2.2	0.0029	-5.83	0.017
Black Meddick	10.2	0.014	-4.29	0.06
Canadian Thistle	9	0.012	-4.42	0.053
Dandelion	9.2	0.012	-4.4	0.053
Kentucky Bluegrass	60.2	0.081	-2.52	0.2
Meadow Brome	138.6	0.19	-1.68	0.32
Meadow Horsetail	0.4	0.00054	-7.53	0.0041
Orchardgrass	156.2	0.21	-1.56	0.33
Mutton Bluegrass	33.8	0.045	-3.1	0.14
Quackgrass	2.6	0.0035	-5.66	0.02
Smooth Brome	242.2	0.32	-1.13	0.36
Narrowleaved Meadowsweet	1	0.0013	-6.62	0.0086
White Clover	81	0.11	-2.22	0.24
			Shannon Index:	**1.8**

Non-Grazed

Species	Ni	Pi	lnPi	-(Pi x lnPi)
Ascending Purple Milk Vetch	0.4	0.00085	-7.07	0.006
Black Meddick	2	0.0043	-5.46	0.023
Canadian Thistle	6	0.013	-4.36	0.057
Dandelion	5.2	0.011	-4.5	0.05
Kentucky Bluegrass	4.8	0.01	-4.58	0.05
Meadow Brome	71.1	0.15	-1.89	0.28
Meadow Horsetail	18.4	0.039	-3.24	0.13
Orchardgrass	80.2	0.17	-1.77	0.3
Mutton Bluegrass	50	0.11	-2.24	0.25
Tufted Hairgrass	32.6	0.07	-2.67	0.19
Quackgrass	1	0.0021	-6.15	0.013
Sandberg Bluegrass	33.2	0.071	-2.65	0.19
Smooth Brome	152.2	0.32	-1.12	0.36
Wild Strawberry	1.6	0.003	-5.68	0.019
White Clover	9.8	0.021	-3.87	0.081
			Shannon Index:	**2**

D. Plant Community Analysis

- **Average heights of Buckbrush (*Ceanothus cuneatus*) in meters for GE and GR:**

	GR	GE
	0.75	0.35
	0.9	0.55
	1	0.35
	0.65	0.7
	0.65	0.6
	0.9	
	0.65	
Average:	0.785714	0.51

- **Woody Species Calculations**

Grazed	# individuals (n)	Density	Relative Density	# of Plots in which species occurs	Species Frequency
Black Poplar	29	0.29	0.805555556	3	0.03
Buckbrush	7	0.07	0.194444444	1	0.01
		0.36			0.04
Non-Grazed					
White Poplar	27	0.27	0.75	2	0.02
Bam	2	0.02	0.055555556	1	0.01
Black Poplar	2	0.02	0.055555556	1	0.01
Buckbrush	5	0.05	0.138888889	1	0.01
		0.36			0.05

Relative Frequency	Coverage (m2 per acre)	Relative Coverage	Relative Importance Value	# of Individuals
0.75	0.01604	0.816700611	2.372256167	29
0.25	0.0036	0.183299389	0.627743833	7
	0.01964		1.5	
0.4	0.02354	0.771803279	1.921803279	27
0.2	0.00226	0.074098361	0.329653916	2
0.2	0.0008	0.026229508	0.281785064	2
0.2	0.0039	0.127868852	0.466757741	5
	0.0305		Average: 0.75	

Circular Area	# individuals/m2)	Circular Area/m2
5.092958179	0.001436212	0.000252227
0.257831008	0.000346672	1.2769E-05
11.02409791	0.001337163	0.000545964
0.101612473	9.90491E-05	5.03231E-06
0.012732395	9.90491E-05	4.90536E-09
0.302593336	0.000247623	1.49858E-05

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